DEMOGRAPHIC EFFECTS OF LEGAL TIMBER HARVESTING ON *Guaiacum sanctum* L., AN ENDANGERED NEOTROPICAL TREE: IMPLICATIONS FOR CONSERVATION

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SUMMARY

Guaiacum sanctum *is a timber tree species from the Americas, considered threatened in eleven different countries, including Mexico, and listed in CITES Appendix II. This species is currently harvested legally in the southern Mexican state of Campeche. Despite its protected status, the current condition of its populations and the effects of harvesting upon them have not been assessed. The conservation status of four unlogged populations were evaluated across Central Campeche by documenting their densities and demographic structures, and then compared the size class demographic structures of one unlogged and three logged populations at different times after harvest (3, 8 and 20 years) to evaluate the effects of timber harvesting upon population structure. Additionally, a regeneration index (proportion of seedlings within the population) was estimated for each of the seven populations. Densities of* G. sanctum *varied from 278 to 1732 stems/ha with ≥1cm at 1.3m·height in Campeche. Differences were found in the population structures of unlogged populations, although the density of seedlings and trees was high in all of the sites. Contrary to expectations, higher densities were found in all size classes in logged populations. Results suggest that current logging practices do not have a drastic negative effect on the density of remaining individuals. Although the results indicate that* G. sanctum *in Campeche is not locally endangered, it is recommend that it be maintained in CITES Appendix II.*

The evaluation of the conservation status of a species is an important prerequisite for implementing conservation action plans, especially for species suspected to be declining in abundance or species threatened by anthropogenic activity (De Grammont and Cuarón, 2006). This is the case of *Guaiacum sanctum* L. (Zygophyllaceae), a timber tree species considered to be at risk in parts of its historic range. *Guaiacum sanctum* provides one example of many taxa requiring detailed conservation assessment (CITES, 2000; González-Espinosa, 2009; López-Toledo *et al*., 2011).

Populations of *G. sanctum* have been exploited for centuries for its medicinal properties and high timber value (CITES, 2000). Because of intensive exploitation and habitat loss, it is currently considered a species under risk of local extinction in eleven countries. It is classified by the International Union for Conservation of Nature (IUCN) as an endangered species (ENC2a) and in Mexico as a species under special protection (SEMARNAT, 2010; González-Espinoza, 2009). Additionally, it has been estimated to be at risk in ten other countries across its original distribution, and is listed on Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES, 2000; López-Toledo *et al*., 2010).

KEYWORDS / Conservation / Demography / *Guaiacum sanctum* / Management / Seasonally Dry Tropical Forest / Yucatan /

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Despite its endangered status, harvesting and international trade of *G. sanctum* timber is still permitted in Mexico (Salmón, 2007). Between 1998 and 2006, an annual average of 142.8m^3 of *G. sanctum* timber and wood products were legally harvested and exported (López-Toledo *et al*., 2008). The main importer of *G. sanctum* wood products is Germany, where they are used in the ship building and liqueur industries (Mickleburgh *et al*., 2003). Despite being legally harvested, there are no studies on the effects of timber extraction on the populations of this species, or basic demographic studies which might justify the need for protection. Therefore, it is of interest to evaluate the status of populations in areas where timber harvest is planned or ongoing.

A first approximation to evaluate the status of tropical tree populations is through the analysis of the size class demographic structures, which may be represented by the total number of individuals in a distribution where classes may represent ages or sizes (Vandermeer, 1978; Condit *et al*., 1998). In the case of shade tolerant tropical trees, a large proportion of juvenile individuals in a distribution may be interpreted as indicators of a stable population with sufficient regeneration, which gives the demographic structure the form of an inverted J (Condit *et al*., 1998). Populations with poor regeneration or with discontinuous distributions (i.e., entire size or age classes without a single individual) may be interpreted as populations in decline or affected by strong disturbances (Medel-Narváez *et al*., 2006). This is the case of many highly valuable timber tree species, such as bigleaf mahogany and several other species from the Amazon and African forests, where their densities are reduced, and their class size population structures show discontinuous distributions and low recruitments after intensive logging (Lawes *et al*., 2007; Grogan *et al*., 2008). Moreover, both field studies and modeling exercises have shown the negative effects of intense individual harvesting through selective logging on the demographic structure of populations, and also on their genetic diversity (Kasenene, 2007; Sebbenn *et al*., 2008).

Conclusions based on analyses of demographic size class distributions have to be drawn with caution, however, because size class distributions and population growth rates may not necessarily be strongly correlated, as size class distributions might also be affected by other demographic variables. For example, in a study with 216 tropical tree species Condit *et al*. (1998) found that the population size class distribution was more associated with growth rate of juveniles and survival in each size class, than with population growth rate. Therefore, estimates of demographic parameters and population growth rates may be used to evaluate the conservation status or the effects of management practices more precisely than just examining demographic structure (Zuidema *et al*., 2007). Nevertheless, an adequate estimation of the above mentioned population parameters involves studies of several years, which is not always possible when concrete recommendations are required in the short term. Furthermore, the estimation of population parameters based on only a few years of observation might yield a largely unrealistic estimation of the status of populations, particularly for long-lived species. In such cases, analysis of the size class distribution of individuals might be the most optimal method to evaluate the status of populations.

In this study differences in the abundance and population structures of *G. sanctum* were evaluated across the state of Campeche. Campeche represents the core area of the distribution of the species in Mexico, and to the best of our knowledge it is the only locality in Mexico and elsewhere where current populations of *G. sanctum* are still legally harvested for timber. The study sought to evaluate two primary hypotheses. First, that population structure in four localities un-affected by recent timber harvesting across Central Campeche should not differ. Second, that three populations with different ages since the last *G. sanctum* timber harvest should have fewer very large individuals as a direct consequence of timber harvesting, and fewer small individuals as a consequence of reduced regeneration by the harvesting of seed producing adults, than another, unlogged, population from the same region. Additionally, the potential of regeneration of *G. sanctum* was evaluated across Campeche based on a regeneration index, estimated as the proportion of seedlings within the population (Medel-Narváez *et al*., 2006). Finally, the basal area removed in each harvested population was estimated. Based on the above analyses, an assessment is provided of the conservation status of the studied populations and the effects that recent timber harvesting has upon them.

Methods

Study species

Guaiacum sanctum is a tree species distributed in deciduous and semi-deciduous forests extending from the Florida Keys, to southern Mexico, Central America and the Caribbean Islands (Chavarría *et al.,* 2001). In Mexico, it is restricted to the states of Yucatán, Quintana Roo, Campeche, Chiapas and Oaxaca, with the most abundant populations found in Campeche (Grow and Schwartzman, 2001; Martínez and Galindo-Leal, 2002; López-Toledo *et al*., 2011). In some portions of its original range it has been almost eradicated as a consequence of timber extraction, such as in the Florida Keys, where a population is only found in Lignumvitae Key (Dertien and Duvall, 2009). That population has recently become vulnerable to natural disturbances, such as the infection by the scale insect *Toumeyea lignumvitae* (Williams, 1993; Schaffer and Mason, 1990), and hurricanes (Dertien and Duvall, 2009). In other sites *G. sanctum* has disappeared apparently as a consequence of land use conversion to agriculture or cattle grazing (Gordon *et al.,* 2003). At least 19 bird species in a seasonally dry tropical forest in Guatemala consume its fruits (Wendelken and Martin, 1986), and mature forest sites where the species is present are important for the conservation of large avifauna near the Calakmul Biosphere Reserve, in Mexico (Weterings *et al*., 2008).

G. sanctum is an evergreen tree that grows up to 25m in height and 60cm diameter at breast height (dbh). Its high specific wood gravity (1.09-1.15g·cm^{-3}) and high resin content makes the wood resistant to insect attack, and gives it auto-lubricating properties that make it suitable for the ship building industry (Porter, 1972; CITES, 2000; Grow and Schwartzman, 2001). The species has also been exploited for the medicinal properties of its resin (Grow and Schwartzman, 2001; Dertien and Duvall, 2009). Estimates of diameter growth rates for adult *G. sanctum* trees indicate that this is a very slow-growing species, with an estimated longevity of >500 years (López-Toledo, 2008). Mexico is the only country harvesting and exporting *G. sanctum* timber to Asia and Europe (CITES, 2000; Grow and Schwartzman, 2001; Gordon *et al*., 2005; González-Espinoza, 2009). All Mexican *G. sanctum* legally harvested comes from natural populations (there are no plantations) in the state of Campeche. The management program of the species, which is applied homogeneously throughout the state, disregarding site conditions, includes harvesting of high quality adult trees >35cm of diameter at 1.3m (dbh) in a given area (stand), which can only be logged again after 20 years (Salmón, 2007). Harvesting is conducted by landowners in collaboration with a timber company which designed and is responsible for implementing the management program. The management of *G. sanctum* harvesting is authorized and supervised by the Mexican government environmental authorities (SEMARNAT-PROFEPA), which in turn comply with alignments of CITES (CITES, 2000).

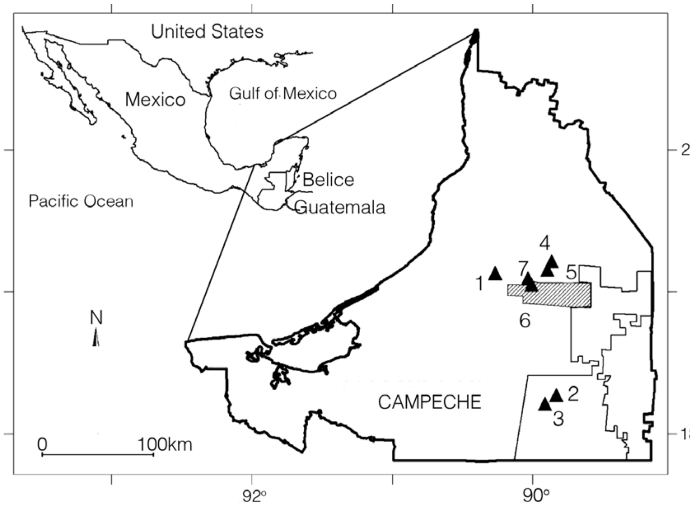

Figure 1. Study sites at Campeche, southeast Mexico. 1: Ejido Carlos Salinas de Gortari (ECSG), 2: Calakmul Biosphere Reserve 1 (CBR1), 3: Calakmul Biosphere Reserve 2 (CBR2), 4: Las Flores (LF), 5: Ejido Pich Forest Reserve 1 (EPFR1), 6: Balam-Kin Reserve (BKR), 7: Ejido Pich Forest Reserve 2 (EPFR2). The delimited solid area indicates the Calakmul Biosphere Reserve and hatched area indicate the Balam Kin State Reserve.

Study site

The study was performed in the southern state of Campeche, in the northern Yucatan Peninsula, Mexico, during Sept-Dec 2004. Seven different populations were located: 1) Ejido Carlos Salinas de Gortari (ECSG), 2) Calakmul Biosphere Reserve 1 (CBR1), 3) Calakmul Biosphere Reserve 2 (CBR2), 4) Las Flores (LF), 5) Ejido Pich Forest Reserve 1 (EPFR1), 6) Balam-Kin Reserve (BKR) and 7) Ejido Pich Forest Reserve 2 (EPFR2). The first four localities represent unlogged populations, at least in the past 35 years, while the last three populations were exploited 3, 8, and 18-20 years before this study was conducted (Figure 1).

According to weather stations of the region (Zoh Laguna, Calakmul Reserve) annual rainfall is ~1100mm with a marked dry season from November to May (Pérez-Salicrup, 2004). Mean annual temperature is ~25ºC. Soils in this region are mainly well-drained karstic hills, although flat lands are also common. *G. sanctum* is mainly confined to the hills (Martínez and Galindo-Leal, 2002; López-Toledo *et al*., 2011).

Sampling

At ECSG, LF, CBR2, and BKR sites, ten 2×50m subplots were established, separated by 25m from one another, following the method devised by Gentry (1982), widely replicated in other tropical sites (Keel *et al*., 1993; Killeen *et al*., 1998). In these subplots, height and diameter at 1.3m (dbh) were recorded for all *G. sanctum* stems >1.5m height, while only height was recorded for individuals ≤1.5m in height. At EPFR1, EPFR2 and CBR1, information based on 1ha plots established to document tree diversity in the region was used. In these plots, dbh and height were recorded for individuals >1.5m height. Height was recorded for individuals ≤1.5m in seventy 2×2m quadrats randomly established within the 1ha plot.

Demographic attributes

The demographic structure of each population was described on the basis of number of individuals in each of six arbitrarily established size categories based on dbh and height (Silvertown, 1987). Individuals <1.0m and 1.0-1.50m height were classified as seedlings (Sdl) and Juveniles (Juv), respectively. Stems >1.50m height and >1.0cm dbh, which are potentially reproductive (López-Toledo, 2008) were classified in one of the following adult categories, Ad1: <10cm dbh, Ad2: 10-20cm dbh, Ad3: 20-35cm dbh, and Ad4: >35cm dbh. To compare among populations with different sampling regimes, the frequency of individuals in each of the size categories was scaled up to 1ha.

Two comparisons were conducted. In the first one the four unlogged populations were compared to evaluate the natural differences in size class population structure across the state of Campeche, and to evaluate whether recently unlogged populations had a demographic size class distribution which suggested insufficient regeneration. Then, one unlogged population (ECSG) was compared to all logged populations (EPFR1, BKR, EPFR2) to explore the effects of logging on population structures. ECSG was used in this comparison as it is geographically close to the logged populations and conditions might be assumed to be similar prior to logging. To explore the regenerative potential of the seven populations a regeneration index was used, estimated as the proportion of individuals <100cm height within the whole population (Medel-Narváez *et al*., 2006).

Basal area removed

Stumps of *G. sanctum* were found in all harvested sites, even in the one harvested 20 years before the present study. While most fallen trees and tree stumps in tropical forests usually decay within a few years (Putz, 1983), the stumps of *G. sanctum* might have lasted longer as a consequence of its high wood density and its resin content. The circumference of all stumps found in the plots with populations logged 3, 8 and 20 years before our study (EPFR1, BKR, and EPFR2, respectively) was measured, and the basal area of each individual stump estimated. The total basal area of removed trees was estimated as the sum of the basal area of remaining stumps, and contrasted with the basal area of living trees.

Statistical analyses

Two factors and their interaction were tested in order to compare population structures: site (with seven levels) and size classes (with six levels). Analyses of deviance were performed, comparing frequencies with a Poisson distribution error and a link log function (Crawley, 1993). In models with Poisson errors, the deviance explained by each factor approximates to

χ^2 values (Crawley, 1993), which were then used to test factor effects. Analyses were completed using Glim 3.7 (Royal Statistical Society, 1985).

To compare the regeneration index across the seven populations, the Mann-Whitney U non-parametric test was used. The test was performed on Systat statistical package V.11 (Systat, 2004). Differences in basal area removed proportional to living tree basal area was explored only visually, as there were not enough points to conduct any type of meaningful regression analysis.

TABLE I
STATISTICS FOR COMPARISON OF POPULATION STRUCTURES OF *Guaiacum sanctum* IN CAMPECHE

Comparison	Factor					
	Site (S)		Size class (SC)		S×SC	
	χ^2	P	χ^2	P	χ^2	P
1- Unlogged	1358	<0.0001	738	<0.0001	2879	0.0017
2- Logged	9567	<0.0001	2527	<0.0001	917	<0.0001

The first comparison evaluates differences in the population structure among four unlogged populations across Central Campeche. The second comparison evaluates differences among one unlogged and three logged populations in Ejido Pich Forest Reserve (Central Campeche). χ^2 and P values refer to analysis of deviance.

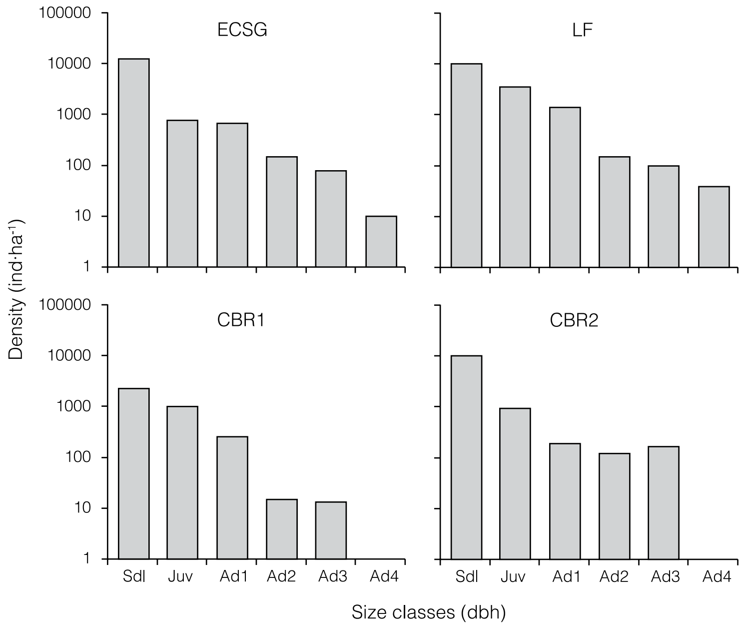

Figure 2. Population structure of *Guaiacum sanctum* at four unlogged populations across Campeche, Mexico. Sdl: seedlings (<1.0m height), Juv: Juveniles (<1.5m height). Stems >1.50m height and >1.0cm dbh, which potentially are reproductive (López-Toledo, 2008) were classified in one of the following DBH categories: Ad1: <10cm dbh, Ad2: 10-20cm dbh, Ad3: 20-35cm dbh, and Ad4: >35cm dbh.

Results and Discussion

Demographic attributes

In total, 3614 reproductive individuals (ind ≥1cm dbh) of *G. sanctum* were recorded in all seven studied populations. Abundance of individuals showed a very high variation across the state of Campeche, with densities that ranged from 278-1732 ind/ha. The highest densities were found in EPFR1, EPFR2 and BKR in Central Campeche, which curiously represent areas of recent past logging. The lowest densities were found at populations within protected areas like those in the Calakmul Biosphere Reserve (CBR1 and CBR2; Figure 1). The fact that recently logged populations have higher abundance of individuals than unlogged populations suggests that forest management does not negatively affect the density of stems in populations, or that variation in densities in natural populations is high enough that the effects of harvesting would be undetectable.

Unlogged populations of *G. sanctum* at the four unlogged sites across Campeche presented an inverted J size distribution, with a high proportion of individuals in the small size classes and fewer individuals in larger classes. However, the analysis of deviance indicated differences in the population structures among the four sites (Table I). The differences were mainly due to the CBR1 population, which had a low number of individuals in all the size classes compared to other populations. Additionally, trees of commercial size (≥35cm dbh) were not recorded at either of the Calakmul populations located in the southern portion of the study area (CBR1 and CBR2), but individuals in this diameter class were well represented in two populations in the north, ECSG and LF (Figure 2).

These differences might be explained by two non exclusive considerations. The first one is the type of forest where populations of *G. sanctum* are located. In the south of the Yucatan Peninsula there are two major forest types that differ in their structure, apparently in response to micro-topographic soil conditions. In low statured forests, which grow in sites with clay soils, tree diameters and canopy heights are lower than in adjacent medium statured forests, where soils are better drained (Pérez-Salicrup, 2004). The site with the lowest tree densities in all size classes was CBR1, which is located in a low statured forest.

The second factor explaining differences is the possibility of past logging activity. The Calakmul Biosphere Reserve includes areas where intensive selective logging was carried out in 1950-1980, and *G. sanctum* was one of the exploited species (Martínez and Galindo-Leal, 2002). Therefore, although no stumps of *G. sanctum* trees were seen in either of the Calakmul Biosphere Reserve sites, they could have been exploited under more extreme and unregulated conditions in the past, potentially explaining a depletion of large individuals. In a recent study, a population of *G. sanctum* near the Calakmul Biosphere Reserve was found to have smaller diameters than the means of other tree species (Weterings *et al*., 2008). Although this difference was not outside the 95% confidence interval, the authors suggested that this could be the consequence of past extraction of large *G. sanctum* individuals in the locality. The density of individuals they report is also lower than the densities found in the present study. It is thus likely that unregulated past logging activity might have reduced the populations in the southern portion of the study area, close to the present Calakmul Biosphere Reserve.

Significant differences were found between one unlogged population (ECSG) and three populations with different periods since logging (EPFR1, EPFR2, BKR; Figure 3, Table I). Surprisingly, logged populations had a higher number of individuals in all the size classes than unlogged populations. This pattern could be caused by the combined effect of the low extraction rate in the area (3-4 trees/ha) and the high abundance of other seed-producing adult trees. This high density in all size classes was particularly true for seedling and juvenile densities, which had densities 1.5-4.5 and

2.5-3.5 times higher, respectively, than in the unlogged population. For the case of adults (stems ≥1.5m in height) the density was somewhat similar among sites, with densities of 910-1732 ind/ha. All populations included in this comparison, with exception of BKR (logged eight years before this study), had trees of commercial diameters in similar densities (9-11 ind/ha).

Unfortunately, not enough sites were found in the region in order to evaluate the relationship between years since last logging extraction and density of commercially sized trees; hence, we cannot provide a strict assessment of the recovery of populations after harvest and of the pertinence of the 20 year logging cycles. However, it was noticed that the population logged 3 and 20 years before our study (EPFR1 and EPFR2, respectively) had trees of commercial size, but not so the population logged 8 years before. It is possible that after 20 years, trees that were left uncut because they were underneath the threshold diameter could have grown to commercial size category (López-Toledo, 2008, López-Toledo *et al.*, 2011). This would explain the presence of commercial size trees in the population harvested 20 years before this study. However, it is also possible that more intensively logged areas, or areas with naturally lower population densities, would require longer periods for the population to include commercially sized individuals (López-Toledo, 2008, López-Toledo *et al.*, 2011). In the case of the population harvested three years before this study, the presence of commercial size individuals must be the result of trees that were either missed or left standing on purpose by the logging company, as it is extremely unlikely that trees would pass from non-commercial to commercial diameter in only three years (López-Toledo, 2008; López-Toledo *et al.*, 2011). Therefore, further analysis, exploring the population dynamics in areas with different years of recovery since the last harvesting, is required to contribute to an improved forest management of this species in the Yucatan Peninsula.

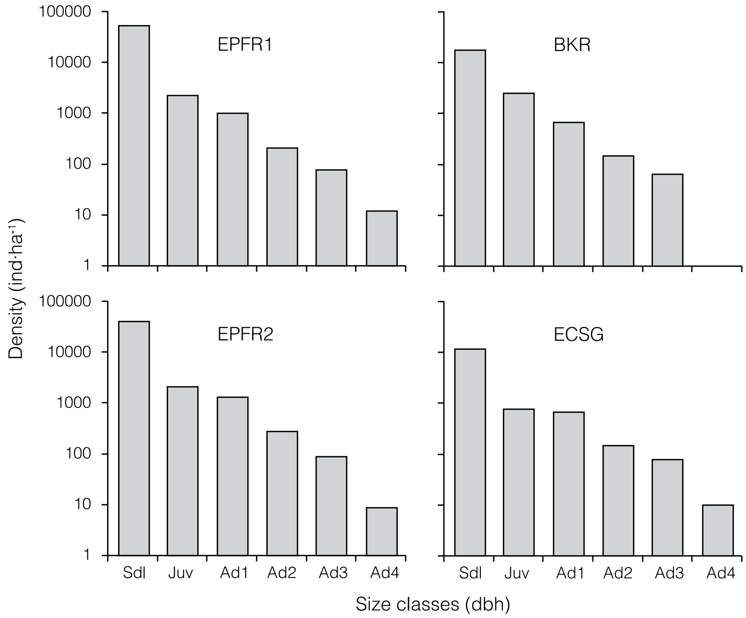

Figure 3. Population structures at one unlogged (ECSG) and three logged populations (EPFR1, EPFR2 and BKR) at Central Campeche, Mexico. For correspondence of size classes see Figure 2.

A high regeneration index (proportion of plants <100cm in height within the population) was found for the seven populations analyzed. Indexes ranged 0.65 to 0.93, which indicates good regeneration of this species across Campeche. The highest indexes were found at the logged populations in Central Campeche (EPFR1= 0.93, BKR= 0.83 and EPRF2= 0.91, respectively), but the Mann-Whitney U test indicated a similar regeneration index across the seven studied populations (U= 10, p≤0.15). Similar results were obtained in previous studies under natural conditions or low intensity management (Stoffers, 1984).

G. sanctum is a shade tolerant species that assimilates the same amount of carbon when growing in the shade or when exposed to solar radiation (Schaffer and Mason, 1990), so seedling growth might not be seriously affected by canopy disturbances associated with forest management. Seedling establishment and survival, however, might increase after canopy disturbances, as suggested by an increase in seedling densities in a Honduran forest following a fire (Otterstrom *et al.*, 2006). Basal area removed in logged sites represented almost 40% of the total basal area of those populations (see below). The removal of commercial sized individuals might have created gaps of enough size to increase the establishment of seedlings. In the present study, reduced numbers of seedlings and juveniles were not found in logged sites, perhaps because sub-canopy trees of this species can reproduce, hence compensating for the propagule production of harvested individuals.

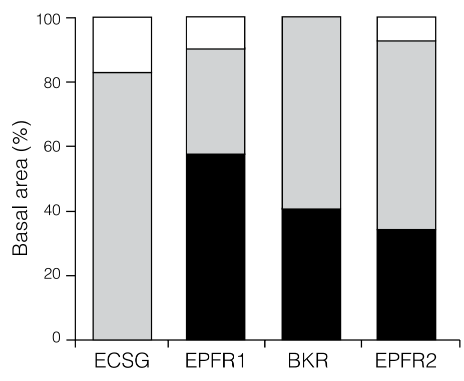

Figure 4. Basal area (%) of one un-logged (ECSG) and three logged (EPFR1, BKR, and EPFR2) populations of *Guaiacum sanctum* in Central Campeche. Black: basal area removed 3, 8 and 20 years before the study; gray: basal area contained in non-commercial adult trees (≥1<35cm dbh); white: basal area in commercial trees (≥35cm dbh).

Based on the results obtained, the total density of *G. sanctum* seedlings and reproductive trees is good in the seven populations analyzed. This suggests that current harvesting of this species might not jeopardize its populations. However, this conclusion should not prevent further studies aimed at evaluating demographic parameters such as growth, mortality and reproductive rates of this species in each size class.

Due to the declining demand of this species in the international market, forest management centered on it might decline in the near future. This may paradoxically result in a potential risk for *G. sanctum* populations, as this would reduce the interest in forest management and increase the pressure for converting the land to agricultural purposes, which is still high in the region (Turner *et al.*, 2001). During our field work we witnessed the sale of 20000ha of forests to private owners who intended to transform forests into plantations, agriculture and cattle raising. *G. sanctum* apparently disappears from landscapes dominated by these land uses (Gordon *et al.*, 2005).

Basal area removed

The basal area removed was similar among the three logged populations (EPFR1= 0.94m², EPFR2= 0.9929m², BKR= 0.93m²), corresponding to trees with a mean diameter (cm ±SE) of 52.2 ±9.6 for EPFR1, 57.1 ±2.8 for EPFR2 and 38.5 ±2.5 for BKR. The basal area from reproductive individuals was similar among the four populations.

Several studies have reported that logging may damage >50% of the original stand. For example, conventional logging of mahogany (*Swietenia macrophylla*) in the Brazilian Amazon may remove up to 95% of the commercial mahogany trees and 30-47% of non commercial trees, while damaging and likely killing trees as small as 20cm in dbh (Grogan *et al*., 2008). Based on stumps, we found between 4-5 logged commercial trees/ha, which accounted for ~40% of basal area of the *G. sanctum* populations, a substantial figure but relatively low compared to other management operations based on *S. macrophylla* in Yucatan (Dickinson *et al*., 2000). The present sample size is low and it was not possible to conduct any further regressions between time since the last harvest and recovery of commercial size individuals. However, the results seem to indicate that current *G. sanctum* logging practices in Campeche might have relatively less impact upon the basal area of the population, than the extraction of other commercial species in the region.

Conclusions

Guaiacum sanctum populations are abundant in Campeche and apparently are not negatively affected by their exploitation. However, we suggest that the species should be kept in CITES and in the Mexican Norm (NOM-059-ECOL-2010), since it is apparently locally extinct or endangered in several sites within its natural range of distribution in Mexico outside of Campeche. Because this species is very long lived, it is necessary to conduct long term studies and obtain the growth rates of *G. sanctum* individuals in different populations, in order to be able to adequately estimate the harvesting rates. It is important to follow demographic trajectory and population dynamics in order to understand the effects of harvesting on the exploited populations and, if appropriate, recommend improvements in logging practices. Finally, although counterintuitive, management of tree species for timber might be one of the few local incentives in this region to reduce the pressure to convert large tracks of forests to agriculture and cattle raising. Such conversion would very likely eliminate *G. sanctum* from the region.

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EFECTOS DEMOGRÁFICOS DE LA EXPLOTACIÓN DE *Guaiacum sanctum* L., UNA ESPECIE MADERABLE NEOTROPICAL AMENAZADA: IMPLICACIONES PARA SU CONSERVACIÓN

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RESUMEN

Guaiacum sanctum *es una especie maderable de las Américas considerada como amenazada en 11 diferentes países incluyendo México y listada en CITES Apéndice-II. Esta especie es aprovechada legalmente en México en el estado de Campeche. A pesar de su estatus protegido, las condiciones actuales de sus poblaciones y los efectos de la cosecha no han sido evaluados. En este estudio se evaluó el estado de conservación de cuatro poblaciones no aprovechadas del centro de Campeche, documentando sus densidades y estructuras demográficas. Adicionalmente, se compararon las estructuras demográficas de una población no aprovechada y tres poblaciones aprovechadas con diferentes tiempos de abandono después de la cosecha (3, 8 y 20 años) para evaluar los efectos de la cosecha de madera sobre la estructura poblacional. Finalmente, se estimó un índice de regeneración (proporción de plántulas en la población) para cada una de las siete poblaciones. Las densidades de* G. sanctum *varían de 278 a 1732 individuos/ha con ≥1cm dap (diámetro a altura del pecho, 1.3m) en Campeche. Se encontraron diferencias en las estructuras de las poblaciones de poblaciones aprovechadas, aunque la densidad de plántulas y adultos fue alta en todos los sitios. Contrario a lo esperado, se encontró mayores densidades en todas las clases en las poblaciones aprovechadas. Los resultados sugieren que las actuales prácticas de aprovechamiento parecen no tener un efecto negativo drástico en la densidad de individuos. Aunque los resultados indican que* G. sanctum *en Campeche no está localmente amenazado, se recomienda mantenerlo en CITES Apéndice II.*

EFEITOS DEMOGRÁFICOS DA EXPLORAÇÃO DE *Guaiacum sanctum* L., UMA ESPÉCIE MADEIRÁVEL NEOTROPICAL AMEAÇADA: IMPLICAÇÕES PARA A CONSERVAÇÃO

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RESUMO

Guaiacum sanctum *é uma espécie madeirável das Américas considerada como ameaçada em 11 diferentes países incluindo o México e listada em CITES Apéndice-II. Esta espécie é aproveitada legalmente no México no estado de Campeche. Apesar de seu estado protegido, as condições atuais de suas populações e os efeitos da colheita não têm sido avaliados. Neste estudo se avaliou o estado de conservação de quatro populações não aproveitadas do centro de Campeche, documentando suas densidades e estruturas demográficas. Adicionalmente, se compararam as estruturas demográficas de uma população não aproveitada e três populações aproveitadas com diferentes tempos de abandono depois da colheita (3, 8 e 20 anos) para avaliar os efeitos da colheita de madeira sobre a estrutura populacional. Finalmente, se estimou um índice de regeneração (proporção de plântulas na população) para cada uma das sete populações. As densidades de* G. sanctum *variam de 278 a 1732 indivíduos/ha com ≥ 1cm dap (diâmetro a altura do peito, 1.3m) em Campeche. Encontraram-se diferenças nas estruturas das populações de populações aproveitadas, mesmo que a densidade de plântulas e adultos foi alta em todos os locais. Contrario ao esperado, foram encontradas maiores densidades em todas as classes das populações aproveitadas. Os resultados sugerem que as atuais práticas de aproveitamento parecem não ter um efeito negativo drástico na densidade de indivíduos. Mesmo que os resultados indiquem que* G. sanctum *em Campeche não está localmente ameaçado, se recomenda mantê-lo em CITES Apêndice II.*